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International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

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REVAMP EXPERIENCE OF 1725 MTPD UREA PLANT[1]

A. Basit and S. Hasan Shah
Fauji Fertilizer Company Limited, Pakistan

SUMMARY

The paper outlines the study to identify bottlenecks, options and approach for the most feasible uprate route. It also covers execution strategy to minimize production loss. Commissioning problems and remedial actions have also been discussed.

The revamp scheme has been successful with reduced energy consumption and the plant operating at enhanced capacity.

The paper also covers considerations for future revamp.

RESUME

Cet exposé décrit l'étude destinée à identifier les points d'engorgements, les options et les approches en vue de trouver les voies les plus faibles pour augmenter la production. Elle discute aussi la stratégie pour minimiser les pertes de production. Les problèmes de réception et les moyens d'y remédier sont également discutés.

Le plan de réhabilitation a été mené à bien avec consommation réduite d'énergie, l'unité fonctionnant à capacité supérieure.

L'exposé examine également des considérations en vue de réhabilitation future.

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1. INTRODUCTION

Fauji Fertilizer Company (FFC) is the leading urea manufacturer in Pakistan with market share of 44%. It is a private sector company, operating two parallel trains of ammonia and urea with installed capacity of 1725 MTPD and 1925 MTPD of prilled urea. Both plants use Haldor Topsoe (HTAS) / Snamprogetti (SP) technologies for ammonia and urea manufacture.

Plant-1 was commissioned in April 1982. Its debottlenecking to increase urea production capacity up to 2105 MTPD was successfully commissioned in March 1992. The plant had produced over 10.0 million MT of urea till December 1997.

Plant-2 features low energy ammonia and urea process by HTAS and SP respectively. The project was completed in a record time of 33 months and urea commercial production commenced on March 21, 1993. The plant had produced over 3.2 million MT of urea till December 1997 at an average service factor of 93.8% and capacity factor of 102%.

FFC achieved 16.49 million man-hours of safe operation without any loss time injury. This has been accomplished by effective implementation of safety awareness programme among employees. FFC plants have been given several awards by National Safety Council (USA) including "1st Place Award", "Outstanding Safety Award", etc.

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[1] *Expérience de réhabilitation d'une usine d'urée de 1725 t/j*

2. BACKGROUND

Urea Plant-1 was able to achieve 100% capacity factor during first year of capacity above design. Service and capacity factors during the initial 5 years of operation were 90.1% and 102.4% respectively.

In 1988, FFC initiated a base study for capacity expansion of NH_3 / urea complex.

3. REVAMP PHILOSOPHY

Uprate of a urea plant usually includes features like reduced feed and utilities consumption, pollution control, reduced maintenance cost and improved product quality, etc.

FFC had targeted production capacity increase with following considerations:

- Minimum investment.
- Low incremental utilities consumption.
- Product quality maintained to original specifications.
- Execution with minimum production loss.

4. REVAMP STRATEGY

Develop Preliminary Uprate Proposal

A preliminary uprate study of whole NH_3, urea complex was launched after 4 years of plant commissioning. A test run plan of plant was developed to identify bottlenecks and maintenance / control problems. Plant load increase in steps of 1% per day was considered safe for data collection. Previous operating data and design specifications of equipment were used as reference. The data compiled along with findings were studied jointly with SNAMPROGETTI (SP) and a technical proposal for uprate was developed.

Reviews and Field Tests

The proposal was scrutinized for various checks as material and utility balance, equipment specifications, control valves and fluid velocities in piping, product quality, etc.

Major checks included following:

- Size comparison of critical equipment with reference SP plants of comparable name plate capacity.

- On-stream field tests to confirm available capacity margin by simulating conditions close to uprate.

- Peak load test of utilities to meet anticipated requirements.

The problems and limitations so established were incorporated in the final revamp proposal.

5. KEY FEATURES

Revamp proposal was defined as increase of the plant capacity to 2105 MTPD (i.e. 122% of original design) from base production rate of 1894 MTPD (i.e. 110% of original design).

Major bottlenecks identified were CO_2 compression, decomposition and vacuum sections, handling of recycle stream and steam / cooling water limitations (Annex 1). Details are given below:

5.1 CO_2 Compression

Two options were available to meet additional CO_2 compression requirement:

- Uprate of centrifugal compressor.
- Additional reciprocating type compressor.

a. Centrifugal Compressor Uprate.

The centrifugal machine driven by steam turbine with design capacity of 30,000 Nmc/hr was a major bottleneck for revamp. To confirm that the machine adheres to design performance curves and to precisely define up rate requirement of compressor train, various field tests were conducted. The checks were aimed to confirm available capacity without hampering machine reliability. Findings of test were as below:

- Demonstrated CO_2 compression capacity was up to 110% of plant load.

- Further compression capacity was achievable with following modifications :

    - Replacement with newly designed rotor and diffusers of both high and low pressure casings.

    - Modification of steam turbine for additional power requirement.

    - Replacement of interstage coolers with larger size as these were limiting during hot weather.

    - Interstage separators design and velocities in piping needed critical review.

    - Up rate of antisurge control valve.

BENEFITS:

- Operational reliability of centrifugal machine is well proven. These also require minimum routine monitoring. Maintenance cost is also very low.

- Up rate of centrifugal machine is standard feature and revamp references with successful experience were also available.

- Incremental energy cost for additional gas compression would be marginal.

DISADVANTAGES:

- Scope of work was very high as it needed complete new internals purposely designed for new capacity. The spare rotor was also required incurring high cost. It also required replacement of interstage coolers to meet heat duty demand. The cost of the up rate was also considerably high and also involved downtime for installation. With such extensive modifications in the field, there was a risk of commissioning and startup problems, which could be of serious nature.

- Up rating of steam turbine for additional power gain of 1300 KW was foreseen.

b. New Reciprocating Compressor

Another choice was to install a smaller capacity compressor for additional CO_2 requirement. A motor driven 4 stage reciprocating compressor of 6000 Nmc/hr capacity was considered to operate in parallel with centrifugal compressor. CO_2 from NH_3 plant was bifurcated to feed both compressors and subsequently after compression the discharged streams were joined before entering into urea reactor.

BENEFITS:

- Independent machine having no direct effect on plant operation. Outage of this machine for forced maintenance had also insignificant production loss as during this period centrifugal compressor could be operated at maximum rating capacity.

- Surplus power margin available in gas turbines was utilized.

- Installation / commissioning of new machine was possible with plant on-stream. This was a key consideration to avoid any risk to running plant and commissioning problems could be catered for separately.

- Cost involved was low in comparison with up rating of centrifugal machine.

- New machine would off load continuous running of centrifugal machine at above 100% load and improve operational reliability of the centrifugal machine.

DISADVANTAGES:

- Reciprocating machine deliver pulsating flow and pose no problem when operated independently. However parallel operation with a centrifugal machine was suspected to pose certain risk due to incompatible flow pattern. Further, no references were available from where experience of such arrangement could be shared.

- Frequent maintenance requirement and separate spares inventory had to be maintained.

- Additional set up including piping intercoolers, special civil foundation for reciprocating machine resulting in extra cost involved.

Selected Option

Option of new reciprocating machine was selected based on technical feasibility and economics. Apprehension of pulsatory flow was taken care of by incorporating special design feature to make delivered flow as uniform as possible. Based on analog simulations a set of restriction orifices in piping and pulsation bottle was included at suction and discharge of each stage. Restriction orifice was also provided in both recycle streams to dampen flow variations. This design philosophy helped to get delivered flow extremely smooth.

The experience of parallel operation of centrifugal and reciprocating machines has been very good. Both the machines are performing trouble free for last six years.

CO_2 Temperature Improvement:

Another factor affecting performance and up rate studies of CO_2 compressor was 3-4°C higher than design temperature of CO_2 received from NH_3 plant. The two CO_2 condensers at NH_3 plant were not performing as per design.

In revamp proposal, a 3rd condenser in series with the original two was considered to lower CO_2 temperature. Meanwhile the design of the original condenser was also reviewed to establish reason for poor performance. Skin temperature mapping of the condenser's shell revealed the presence of 150-200 mm condensate layer in the bottom part blanketing 6-8% of heat transfer area. (See Annex-II).

Additional 02 drain points were provided and condensate drainage improved the condenser performance close to design. Drop of 5°C in CO_2 temperature was achieved resulting in approximate 1% saving in power requirement of CO_2 compressor.

The provision of 3rd condenser as part of revamp package was dropped due to above development.

5.2 H.P. Synthesis Loop

In H.P. loop, no addition was made. Only following modifications were carried out:

- To handle increased recycle load; internals of carbamate ejector were replaced. Also H.P. carbamate pumps were uprated. The modification included installation of larger size impeller with inducer and diffusers.

- A set of 3 reciprocating pumps for ammonia feed were provided in original design out of which 2 remained in operation with one standby. As per SP material balance original pump capacity was sufficient to meet NH_3 requirement. Accordingly no provision was made in revamp package. But considering volume expansion of liquid NH_3 in hot season and pumps maintenance history, it was decided to uprate the reciprocating pumps.

- The required additional pumping capacity was handled out of DBN scope. Options considered were :

1. A single centrifugal pump of DBN capacity rendering all 03 reciprocating pumps as standby.

2. 4th reciprocating pump of identical capacity. In this case 3 pumps will be in service against 2.

3. Uprate of only 2 pumps out of 3.

Option 3 was selected based on economic and technical feasibility. Up rate scope included increase in stroke length and cylinders bore with other mechanical modifications. Presently combination of one up rate pump with original capacity pump is sufficient to meet NH_3 requirement.

- Working of fairly accurate NH_3 pumping requirement for DBN case was grey area as it is dependent upon NH_3:CO_2 ratio to be maintained in H.P loop, NH_3 losses and recycled NH_3 vapours. NH_3 flow rate at various plant loads was plotted against NH_3:CO_2 ratio and the profile extrapolated to establish. NH_3 pumping requirement for revamp case (Annex-III). An important check for up rate of H.P NH_3 pumps is not to allow discharge pressure drop below minimum point of motive pressure for satisfactory performance of carbamate ejector.

  Up rating of NH_3 pumps had resulted in improved plant capacity factor and enhanced operational reliability. Maintenance requirement has also reduced significantly due to pump operation at relatively less speed.

5.3 M.P. Section

Increase in decomposition load was foreseen and catered as below:

- A new "Pre M.P. Decomposer" was included. This is a shell and tube type heat exchanger with heat duty of 4.8 MMKcal/hr. Heating media is LMS steam with 5°C temperature rise of process stream.

- Modifications in original M.P. Decomposer were dual entry of process stream, increase in distribution holes from 8 to 12 mm and ferrule hole size from 4.0 to 4.5 mm.

- Vapours from M.P.D. were routed through shell of new "Preconcentrator". These vapours on condensation give off heat to concentrate urea solution from 71% to 85% on tube side.

  This equipment has 3 portions. The top is vapour separator and liquid distributor with ferrules. Middle part is shell and tube heat exchanger with heat duty of 8.9 MMKcal. Bottom part is solution holder.

5.4 L.P. Section

Distributor and ferrule holes of L.P Decomposer were enlarged from 8 to 12 mm and from 3.0 to 3.2 mm respectively to avoid flooding. Uprate of L.P. Carbamate pumps was dropped due to excellent operational history of pump and magnitude of production loss involved in case of outage of one pump.

5.5 Vacuum Section

Generally vacuum sections are designed with sufficient margin. However, to reduce steam consumption and maintain product quality within original specifications, a new preconcentrator operating at vacuum of 0.35 ATA was added upstream of vacuum section. Two solution transfer pumps were also provided:

The vacuum section up rate was handled by the system supplier, Graham, USA with following changes:

- Replacement of 2nd stage ejector and condenser with larger size.

- Replacement of small ejectors for increased load.

5.6 Steam Network

To meet additional heat duty demand, a new pressure level steam operating at 5.7 ATA and 160°C temperature was included by provision of a thermocompressor (Annex-IV). An ejector system to combine high pressure steam (27 ATA) and low pressure stream (4.5 ATA) to generate low intermediate steam (LMS) at 5.7 ATA. This LMS steam was used for M.P. predecomposer and 2nd stage vacuum condenser. This also helped utilization of excess LS steam generated by its upgradations.

5.7 Waste Water Section

No major modification was carried out except injection of direct steam to distillation tower against original reboiler arrangement to utilize surplus LS steam generation.

5.8 Control Valves Uprate

A number of control valves were up rated / replaced with larger size to meet new loads. (see Annex V).

6. EXECUTION STRATEGY

- The package implementation was phased out availing turnarounds / shutdowns to save production loss. Risks by phasing DBN modifications on operating plant were carefully evaluated.

- Partial benefits with DBN implementation in phases were realized before completion of the package.

7. POST-COMMISSIONING PROBLEMS AND REMEDIAL MEASURES

- Time for startups increased due to change in plant behavior. The operating practices before DBN needed changes due to following observations:

* System hydraulics changed with addition of pre-concentrator, its associated piping and difference in equipment elevations. Time required to establish L.P. circulation increased significantly. Also plug flow pattern observed in M.P. absorber and its level control became difficult. There were incidents of abrupt high level in M.P. absorber and consequent CO_2 slippage resulting in vapour locking of NH_3 booster pumps.

* New LMS steam header had no auto pressure control. As a result, frequent lifting of PSV on LMS header observed due to variations in steam consumption.

* Manual vacuum control of pre-concentrator (by adjustment of motive steam to ejector and cooling water to condenser) resulting in crystallization in the holder.

* Level control problem in pre-concentrator holder resulting in vapour locking of urea solution pumps and lumps formation in 1st vacuum separator.

7.1 Remedial Measures

- Startup procedure were modified to incorporate new operational practices according to system behavior. Also M. P. absorber level control valve up rated for quick handling of abrupt level rise.

- A split range pressure control loop to LMS steam header provided.

- Auto vacuum control loop of Pre-concentrator similar to one installed on Ist vacuum separator provided.

- Level probe length of Preconcentrator was increased to improve NPSH for solution transfer pumps. A vortex breaker also provided in Preconcentrator holder to improve pump suction conditions.

8. PLANT PERFORMANCE AFTER REVAMP

Revamp proposal was successful with following achievements:

- Production capacity increase by 70,000 MT/Year. Capacity factor improvement is shown in Annex-VI. The average capacity factor after DBN has been 123%.

- Saving of about 10 tons/hr steam and 600 M^3/hr cooling water was realized due to heat recovery in the pre-concentrator.

- Energy consumption decreased by 0.12 Gcal/Ton (10% energy saving).

- Product quality remained well within design limits.

9. PROJECT COST AND PAY BACK

Initial project cost of ammonia and urea complex revamp was US $ 13.7 Million. With extensive studies and field tests, revamp scope of work was revised and actual cost of complex revamp reduced to US $ 10 Million. Major part of the revamp cost was on urea unit i.e., US $ 7 Million. The project evolved as good investment with attractive pay back of only 2.2 years.

10. FUTURE REVAMP CONSIDERATIONS

Further revamp to increase urea plant capacity to 2450 MTPD (142% of design) from existing 2105 MTPD (122% of design) has been proposed. Ammonia plant will also be uprated to 1420 MTPD from 1220 MTPD to meet proposed urea plant requirements.

10.1 Identification of Potential Bottlenecks

Preliminary study was carried out by FFC for next uprate phase to identify potential bottlenecks. Subsequently SP engineers also conducted a site survey to precisely know, what margins are available in the urea plant equipment. Detailed material balance for proposed capacity was carried out jointly by FFC and SP engineers and base case was prepared.

Major bottlenecks identified were CO_2 compression, all major pumps, decomposition and vacuum sections and Urea waste water section.

10.2 Salient Features of Base Case

Preliminary evaluation of existing urea plant performance reveals that there are very little margins available in the present scheme and following the conventional approach for revamp, proposed capacity up rate will not be feasible. However, proposed capacity can be achieved if some major modifications in process scheme to be carried out.

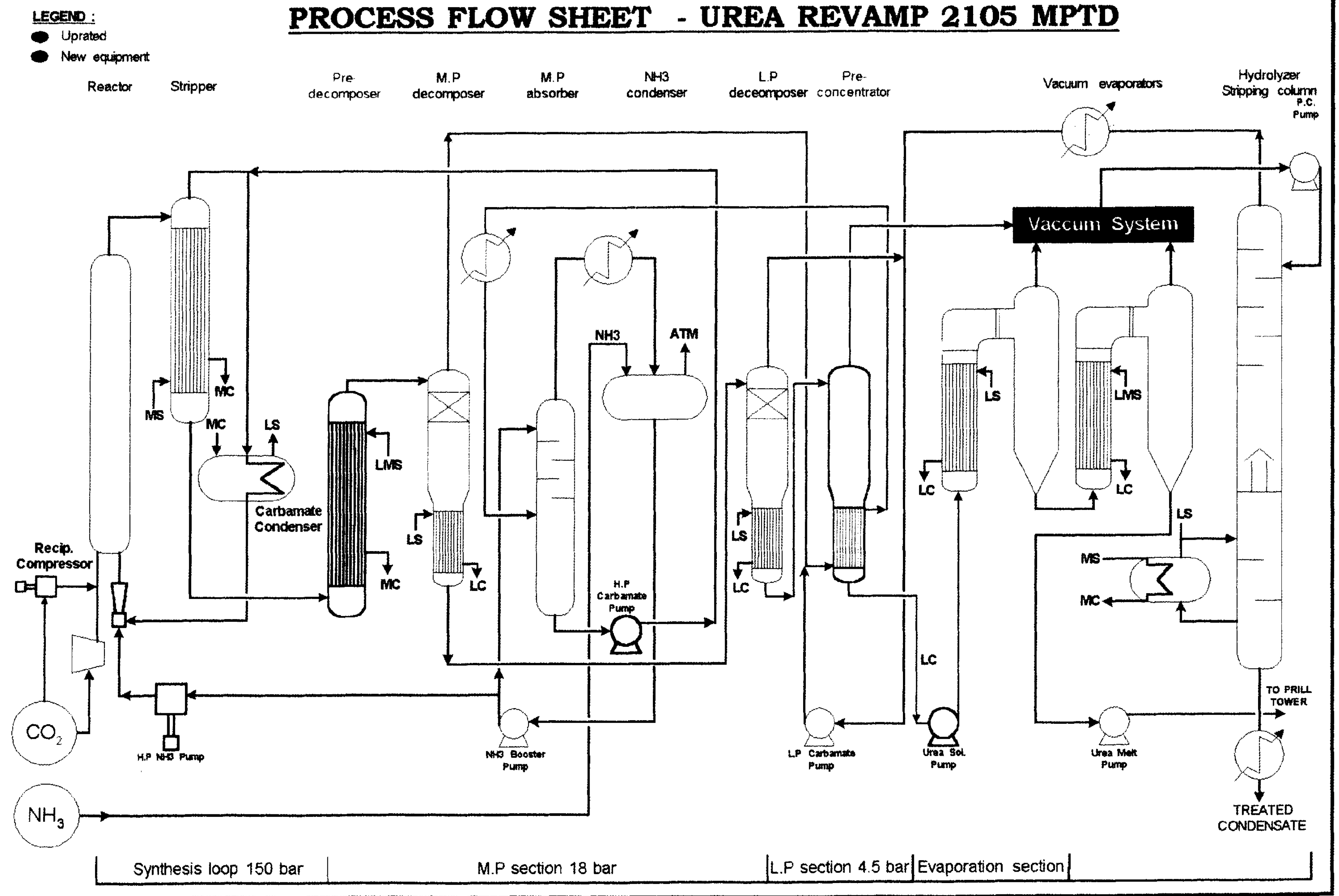
Keeping in view of above, base case was developed with new process scheme. Salient features of proposed scheme are as below:

- ***Addition of new section between HP & MP section.*** This intermediate stage will operate at ~ 90 Kg/cm^2 and will strip 25% of CO_2 and NH_3 from the bottom of existing stripper. The main purpose of this stage is to reduce load on existing HP, MP and LP section. Following advantages will be obtained with the addition of new section:
  - ❑ Reduction in CO_2 tripping load to downstream section, uprating of HP Carbonate pump, P-102A/B will not be required.
  - ❑ More ammonia is recovered to HP section, this way two major benefits will be obtained:
    - Reduction in operating capacity of HP pumps, P-101A/B/C. No uprating is required.
    - Off load existing ammonia recovery system by reducing the duty of ammonia condenser, E-110, which is already limiting.
  - ❑ Less water recycling to urea reactor, thus improving reactor conversion.
- ***Uprating of CO_2 compression section is required.*** However, CO_2 suction temperature will be reduced by 5 ^oC by incorporating low energy features of Benfield System, this will help to utilize available capacity of main Centrifugal Compressor.
- ***No major modifications in existing scheme*** i.e., synthesis and decomposition sections. However, additional trays in urea reactor will be installed to improve Urea reactor efficiency.
- ***No uprate required for major pumps*** i.e., HP NH_3 feed pumps and HP carbonate pumps. However, almost all other pumps need uprating.
- ***Uprating of vacuum section and prilling conveying system will be required****.*
- ***Modifications in urea waste water sections will be required***. A new distillation tower along with a larger size urea hydrolyzer will be installed. By this urea wastewater will also be recovered as BFW quality water, similar to that at our expansion unit where urea wastewater is being recovered as BFW.
- ***Require minimum modifications in existing scheme.*** This will reduce downtime required for uprating.
- ***More energy efficient*****,** introduction of ammonia preheater will increase LP steam export to battery limit.
- ***Although the idea of intermediate stage between HP & MP section*** is not yet proven by experience in SP plants. However, considering existing technology of carbamate decomposition at descending pressure levels, the idea seems workable.

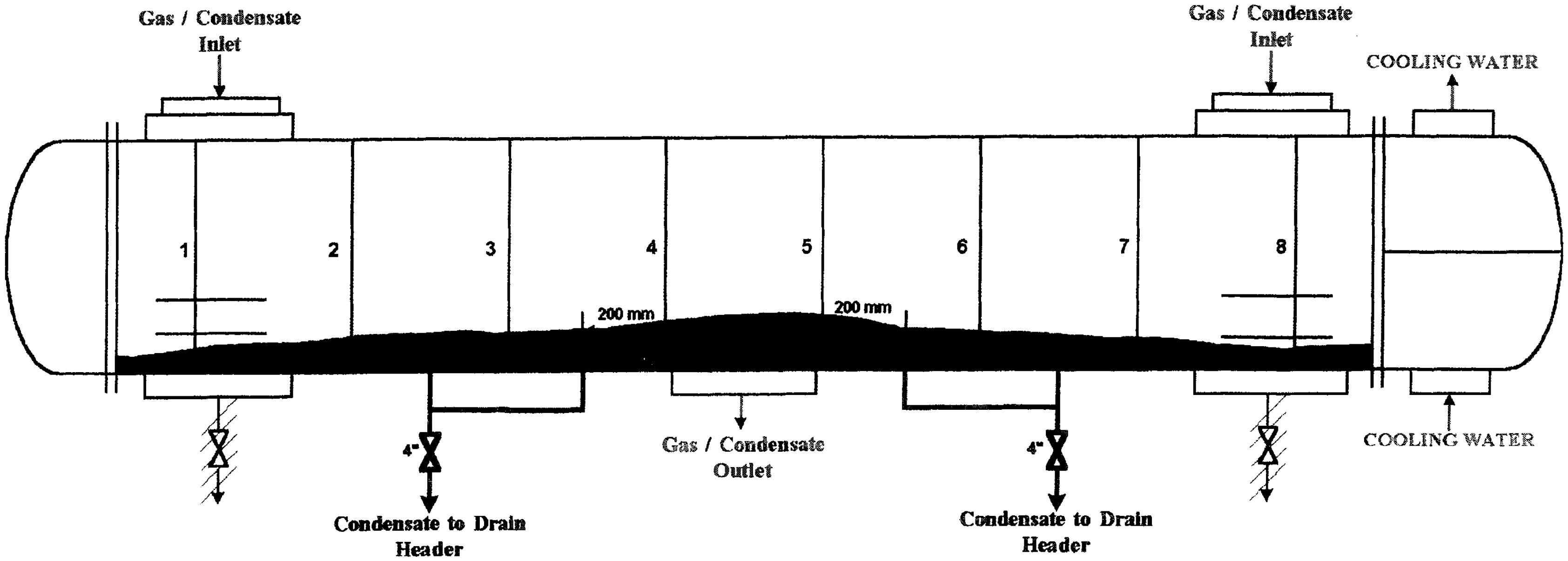
10.3 Project Economics

Estimated project cost for revamping of both ammonia and urea plants will be around US$ 35.0 million with annual increase in urea production of 100,000 MT. Cost of revamp for urea plant will be ~ US$ 10.0 million.

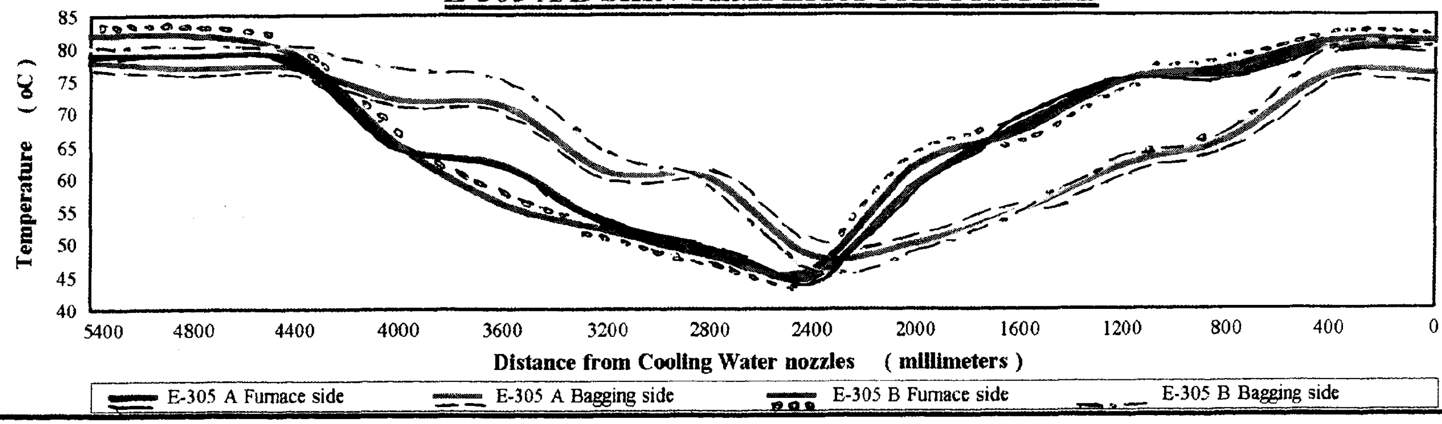
PROCESS FLOW SHEET - UREA REVAMP 2105 MPTD



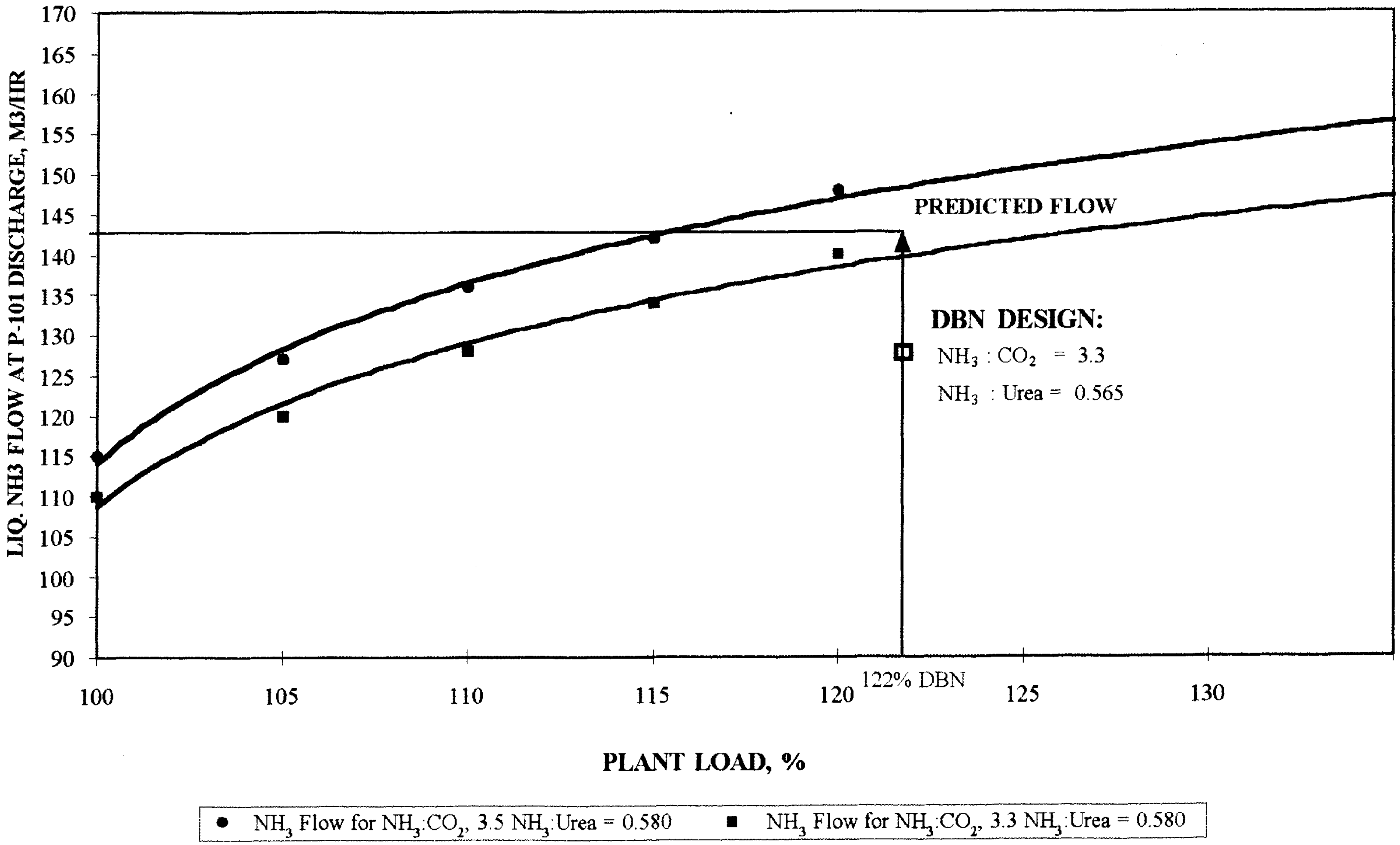
THERMAL EFFICIENCY IMPROVEMENT OF BENFIELD OVERHEAD CONDENSERS E-305A/B



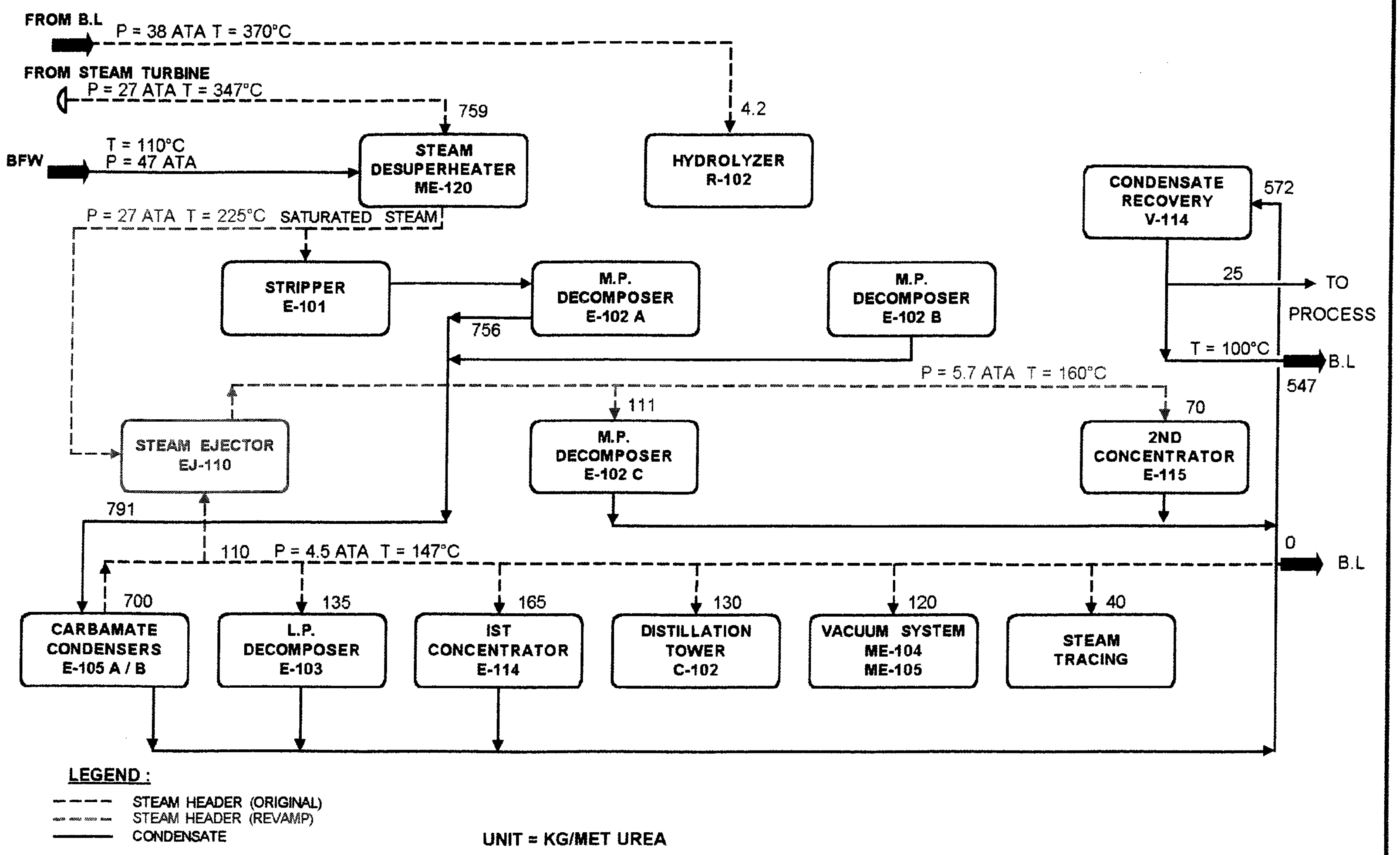
E-305 A/B SKIN TEMPERATURE PROFILE



LIQUID NH3 FLOWRATE AT P-101 DISCHARGE UREA REVAMP 2105 MTPD

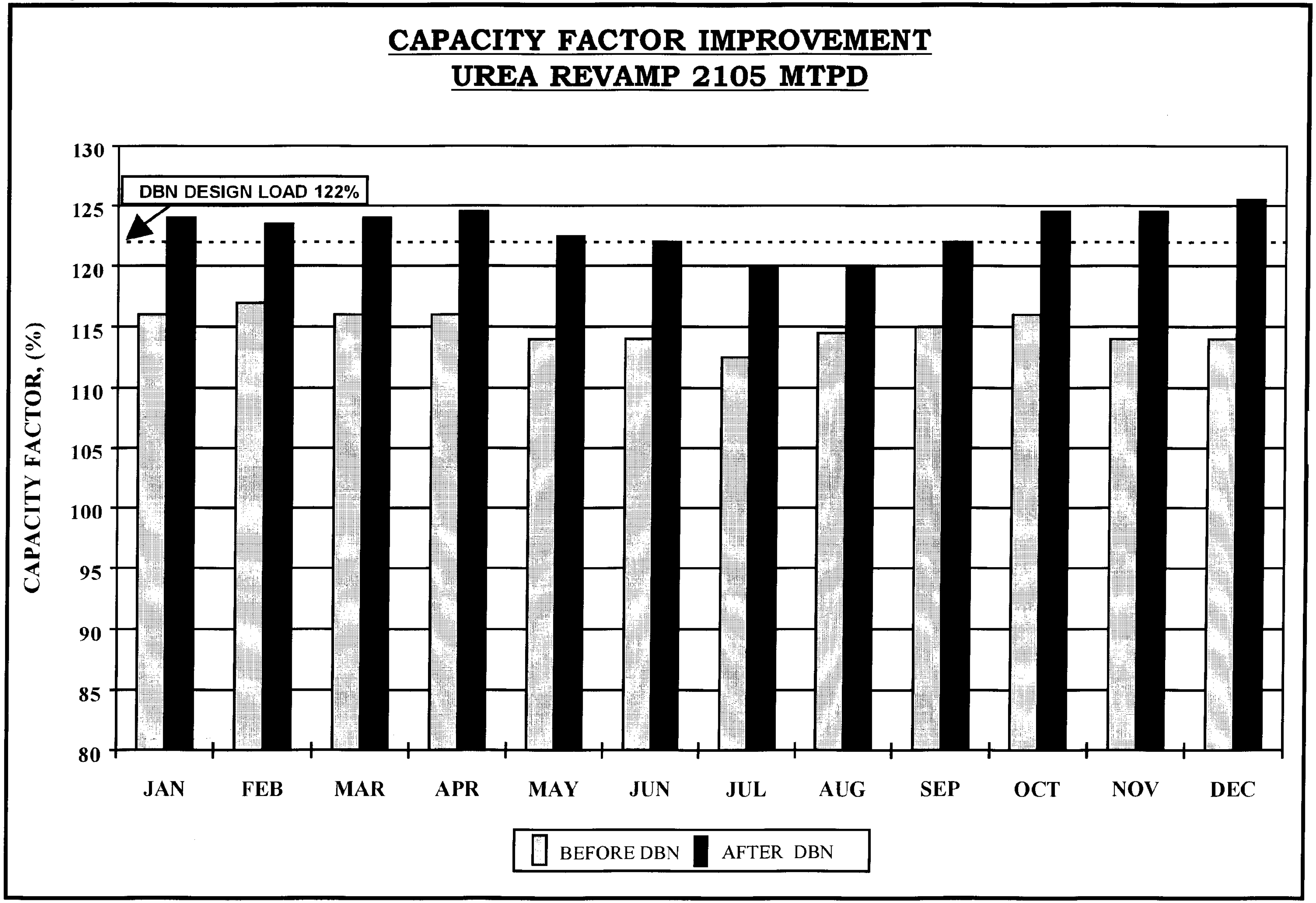


STEAM BALANCE - UREA REVAMP 2105 MTPD



CONTROL VALVES STATUS
UREA REVAMP 21-5 MTPD

S/NO.	TAG NOS.	SERVICE	OLD CV	NEW CV	REMARKS
1	01-PRC-1V1	RECYCLE VAPOURS TO MPD.	7.8	15	TRIM CHANGED
2	01.2-TRC-4V	MS STEAM TO MPD (E-102B).	35	136	NEW VALVE INSTALLED
3	01.3-TRC-3V	LS STEAM TO LPD.	635	1800	-DO-
4	01.2-LRC-9V	MP ABSORBER LEVEL.	43.4	92	-DO-
5	01.3-FIC-10V	REFLUX TO C-102.	1.7	10	-DO-
6	01.4-TRC-10V	LMS STEAM TO 2ND VAC. EVAPORATOR.	450	1410	DISK ANGLE INCREASED FROM 60 TO 90°.
7	01.3-LIC-15V	WASTE WATER EXPORT	55	86.7	NEW VALVE INSTALLED.
8	01.3-PRC-22V	LP SECTION VENT	11	23	NEW VALVE INSTALLED.
9	01.3-FIC-25V	LS STEAM TO C-102	NEW VALVE	800	-
10	01-LIC-25V	PRE CONCENTRATOR LEVEL CONTROL	NEW VALVE	182	-
11	01-PRC-2V	RECYCLE CARBAMATE EJECTOR		-	NOZZLE SIZE INCREASED


CAPACITY FACTOR IMPROVEMENT
UREA REVAMP 2105 MTPD
DBN DESIGN LOAD 122%
CAPACITY FACTOR, (%)
130
125
120
115
110
105
100
95
90
85
80
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
BEFORE DBN
AFTER DBN